MOBILE EXPERTS

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MOBILE EXPERTS GkM MODEL:

Using Traffic Density to Predict LAA, CBRS, 5G deployment

Executive Summary

Network capacity keeps growing to handle rising traffic demand, and Mobile Experts has developed a tool to track mobile traffic density (Gbps/km2/MHz or GkM). This tool has been very accurate and helpful in predicting the timing of small cell deployment.

This report projects the future levels of GkM for key networks in the USA, Korea, Japan, and China, considering the impact of new spectrum in unlicensed and 5G licensed bands. Based on current plans of leading operators, we are setting a tentative marker at 0.18 GkM, indicating a level where the mobile network is heavily utilized and wide-scale 5G investment can be justified.

Background: GkM Model

Five years ago, Mobile Experts created the GkM model as a way to track mobile traffic density, and we began tracking traffic density in some key mobile networks to better understand the drivers of network architecture changes.

Over the past five years, this model has been proven to be a very accurate predictive tool, in estimating the timing of small cell introduction for various mobile operators around the world.

First Step: Looking at Traffic Density

Average traffic density in an LTE network is actually very low, with only about 20-30 kbps/km^2 as an average figure worldwide. However, in urban centers the traffic load is about four orders of magnitude higher… about 150 Mbps/km^2 throughout the day. To make things worse, during the peak hour of the day, the traffic load can be 5-10X higher than average, and also key hotspots within the city can be loaded with far higher traffic demand than the average city street.

It's important to examine localized peak traffic because mobile operators make decisions about network architecture as they upgrades. Localized peak traffic can be about 50X higher than average urban traffic levels, due to:

- Heavy use of social media and video consumption at lunchtime or commute times;
- Crowds of people gathering to wait for a train or other transportation;
- Activity happening on the street (such as an auto crash) can generate spikes of video uploads;
- Special events such as concerts, sporting events, etc;

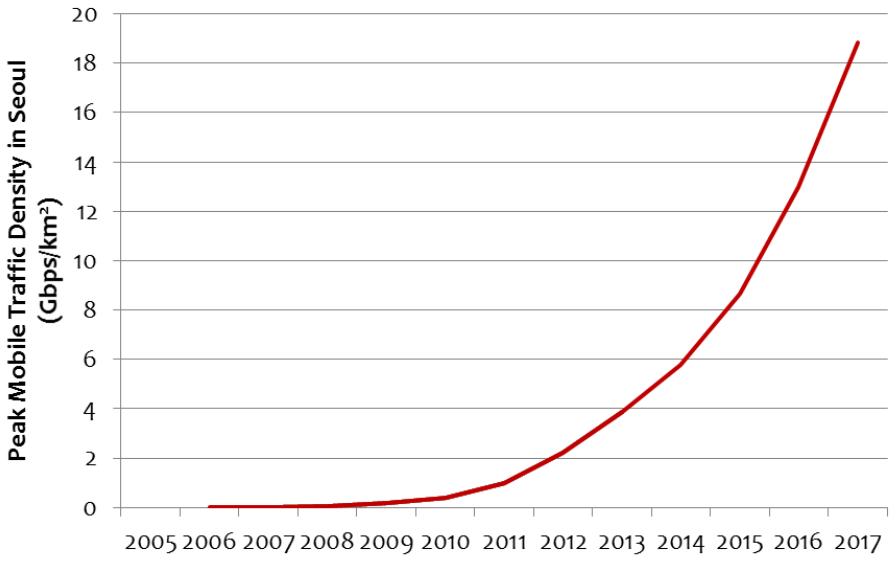

Figure 1 Hotspot Peak-hour traffic density in Seoul

Source: Mobile Experts

Second Step: Adjust for Available Spectrum

Mobile operators with wide blocks of spectrum can handle high peak traffic demand most easily, because they can simply deploy more macro base station equipment and achieve both coverage and capacity. However, when spectrum is constrained, the traffic density per MHz of spectrum starts to shoot upward rapidly.

Over the past five years, Mobile Experts has noticed that leading mobile operators in Korea, Japan, and the USA have experienced a pronounced rise in traffic density per MHz, measured in Gbps/km²/MHz (GkM).

	Data Density (Gbps/km2)	Licensed Spectrum (MHz)	GkM
Seoul	18.8	145	0.130
Tokyo	16	150	0.107
New York	5.7	125	0.046
London	4.3	210	0.021
San Francisco	5.4	135	0.040
Rio de Janiero	1.8	75	0.023
Mexico City	0.7	78	0.009

Figure 2 Mobile data density for various world cities (2017)

Source: Mobile Experts

Mobile Experts calculates Gbps/km2/MHz, normalizing traffic density for the total amount of uplink and downlink 2G/3G/4G spectrum available. In the past, we did not include unlicensed spectrum, but this year we have changed our model to include spectrum in the 5 GHz UNII bands, as well as the 3.5 GHz CBRS band. We're also projecting large blocks of 5G spectrum to enter the market in multiple countries.

Third Step: Use the GkM metric as a predictive tool

Over the past five years, we have noticed that every mobile operator begins to deploy small cells when the network reaches a GkM level of 0.02. It's an economic decision: at that level of traffic density, it's cheaper to install a local small cell instead of boosting the capacity of a series of macro towers. This works well because the demand is spotty, and isolated small cells can solve the capacity crunch very cost-effectively.

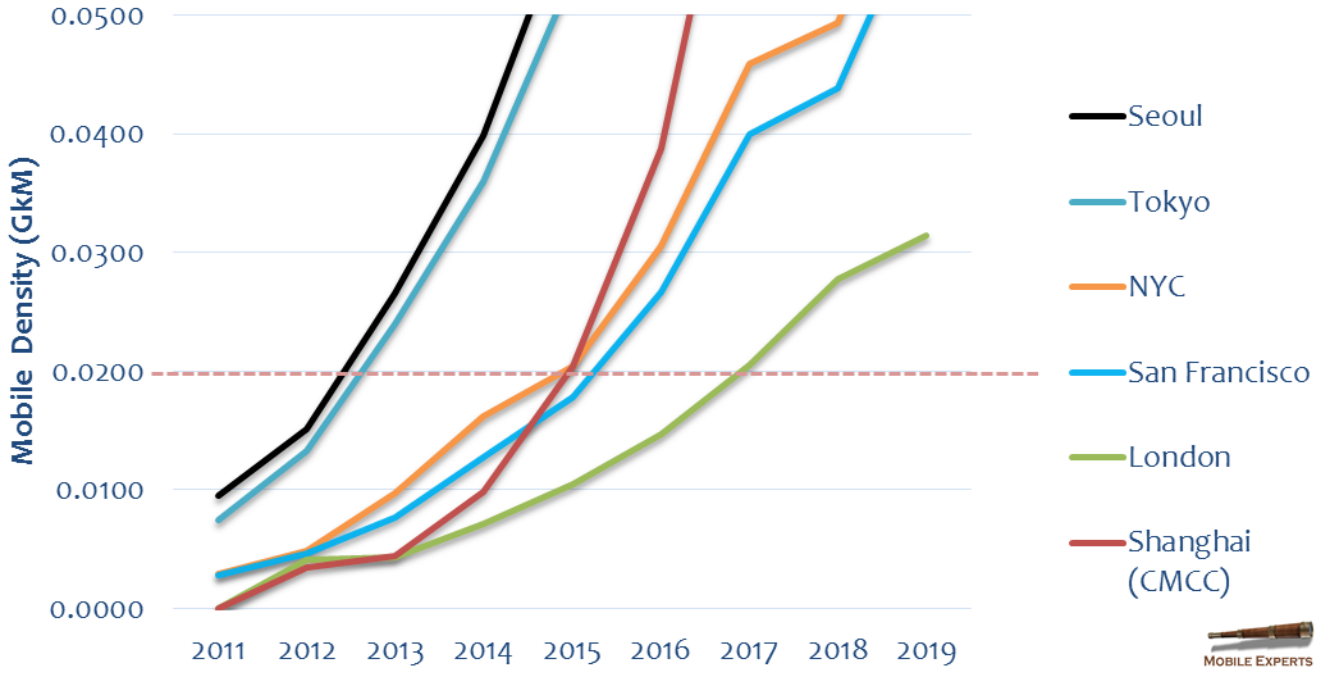

Figure 3 GkM correlates with small cell timing

Source: Mobile Experts

The correlation holds true for SKT, KT, NTT DoCoMo, KDDI, Softbank, Verizon, AT&T, China Mobile, and EE so far. In all cases, mobile operators that exceed the threshold value of 0.02 GkM begin to deploy small cells because it's economically better than more macro sites. Seoul and Tokyo were first, with RRH units in the 2011 to 2012 timeframe. In the USA, major small cell

deployment started in 2015. Also, in China, operators began heavy use of Distributed Radio Systems like the LampSite to add significant capacity. In London, density is just starting to reach the critical level in 2017 and we see upcoming deployment of small cells.

Based on the strength of this correlation, the Mobile Experts small cell forecast has been remarkably accurate, with less than 5% difference between forecasted shipments and actual shipments over the past two years.

Current Levels of GkM

As GkM shoots higher, we expect new problems to arise. Small Cells can be deployed in incremental steps, but "cell splitting" in the case of small cells will pose big RF interference challenges and logistical challenges with regard to light poles or street furniture.

Today, the busiest parts of Shanghai, Seoul, and Tokyo have reached GkM levels of between 0.07 and 0.13. Seoul is the highest due to limited spectrum availability and very high cultural adoption of LTE data. Tokyo also has limited spectrum today, with strong demand due to heavy use of trains for transportation. China Mobile is an interesting case, because they have more spectrum than other operators (245 MHz)---so even though demand is similar to Korea and Japan, China's GkM density is half of the levels in Korea.

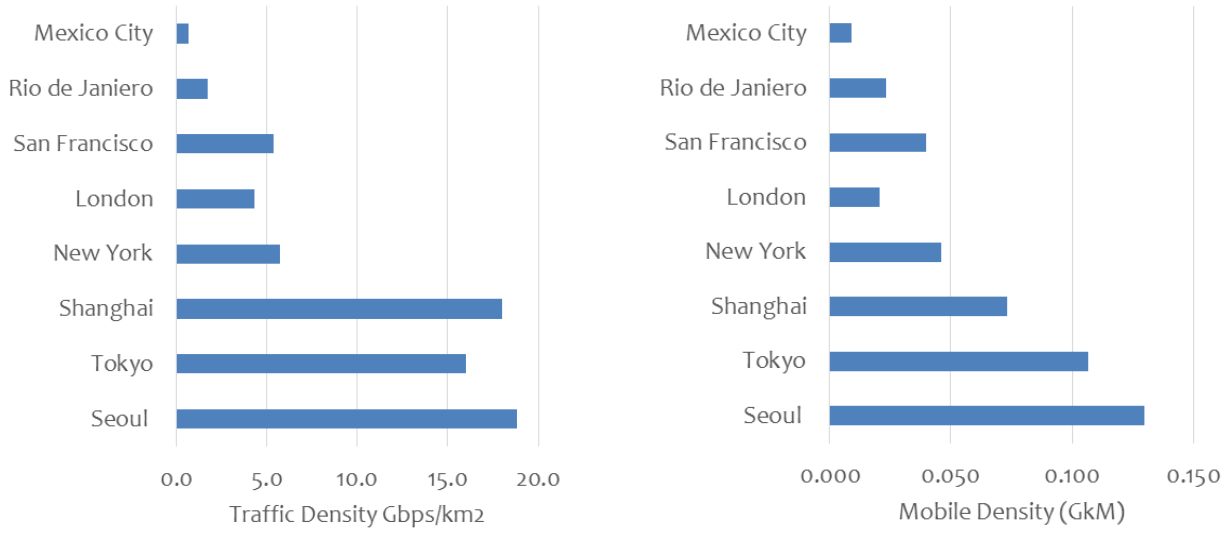

Figure 4 GkM for key cities in 2017

Source: Mobile Experts

Future levels of GkM

The last five years have been relatively simple to track because the spectrum available to each operator hasn't changed much. The operators have been working with a few blocks of LTE

spectrum that were licensed in the 2008-2011 timeframe, and gradually deploying RF channels until all of the channels were occupied in urban hotspots.

Going forward, the picture gets more complex because LAA, CBRS, and 5G spectrum will come online. As new spectrum is added, GkM levels will *drop* instead of rising.

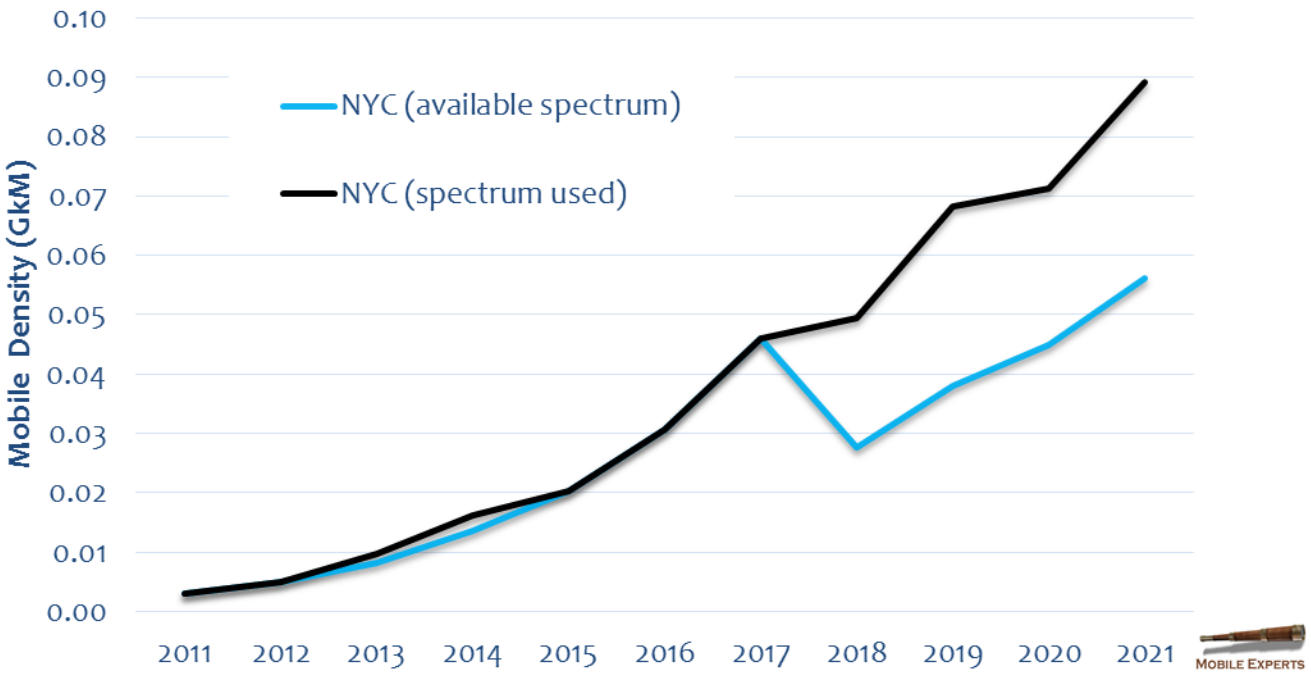

Figure 5 GkM based on available spectrum or used spectrum

Source: Mobile Experts

It's important to keep track of how much spectrum is actually used by the operators. For example, in the US market, LAA will be utilized beginning in 2018, with a total of 680 MHz available. However, other users will occupy the UNII bands, so in crowded locations each operator is only likely to have access to about 25% of the UNII bands or 170 MHz. In practice, LAA-enabled small cells are likely to use a 40 MHz LTE channel in the UNII band, so for the near term the operators won't be using the roughly 170 MHz that we consider "available" to them.

In our view, the best tracking metric will be to keep track of traffic density according to the spectrum that's actually used, so we show GkM charts according to the spectrum utilized, not the spectrum "available". Of course, both factors are important because hotspot solutions like small cells can inexpensively grow in capacity as long as wider LAA bands can be used. When the "available" spectrum runs out, the operator will need to turn to 5G or other solutions.

In each country, we have estimated the timing of LAA deployment and 5G deployment, with CBRS added in the US market. So far, we have ignored the impact of mm-wave spectrum (see the mm-wave secton below to assess its impact on GkM).

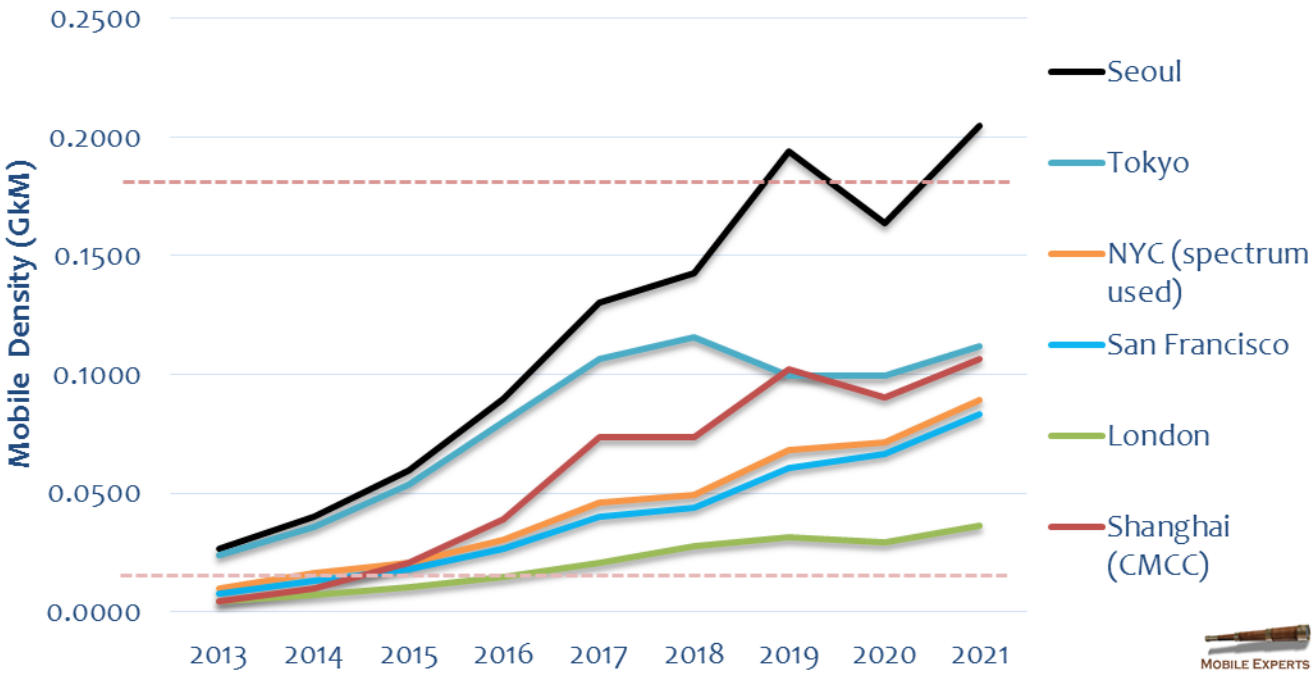

Figure 6 GkM predictions based on traffic and spectrum growth

Source: Mobile Experts

One conclusion that we make is that we'll see Korean networks hit a maximum of about 0.2 GkM in the 2019 timeframe… and then come down with 5G spectrum at 3.5 GHz. If Korean operators don't quickly turn to mm-wave spectrum for 5G, their GkM number will keep increasing despite the impact of 5G in the lower bands.

Mobile Experts will be tracking the performance of Korean networks as they reach GkM values above 0.15. Is there a practical ceiling? Does the mobile network get "saturated" at some level, where interference becomes difficult to control and further densification would be cost-prohibitive? We have tentatively set a threshold of 0.18 to 0.2 GkM, where ongoing increases in demand cannot be satisfied with low-cost capacity… and new spectrum or Massive MIMO will be needed to achieve higher capacity.

The impact of mm-wave spectrum

Adding a big chunk of spectrum in the 28-40 GHz range can make a big difference in localized density of traffic. In Korea, SKT and KT plan to use the 28 GHz band to augment capacity for urban hotspots. Each operator is expected to get 1 GHz of spectrum between 26.5 and 29.5 GHz. Assuming that products would be ready in the 2021 timeframe, this band could drop Korean GkM values from about 0.2 to 0.07, returning the level of density to 2015 levels.

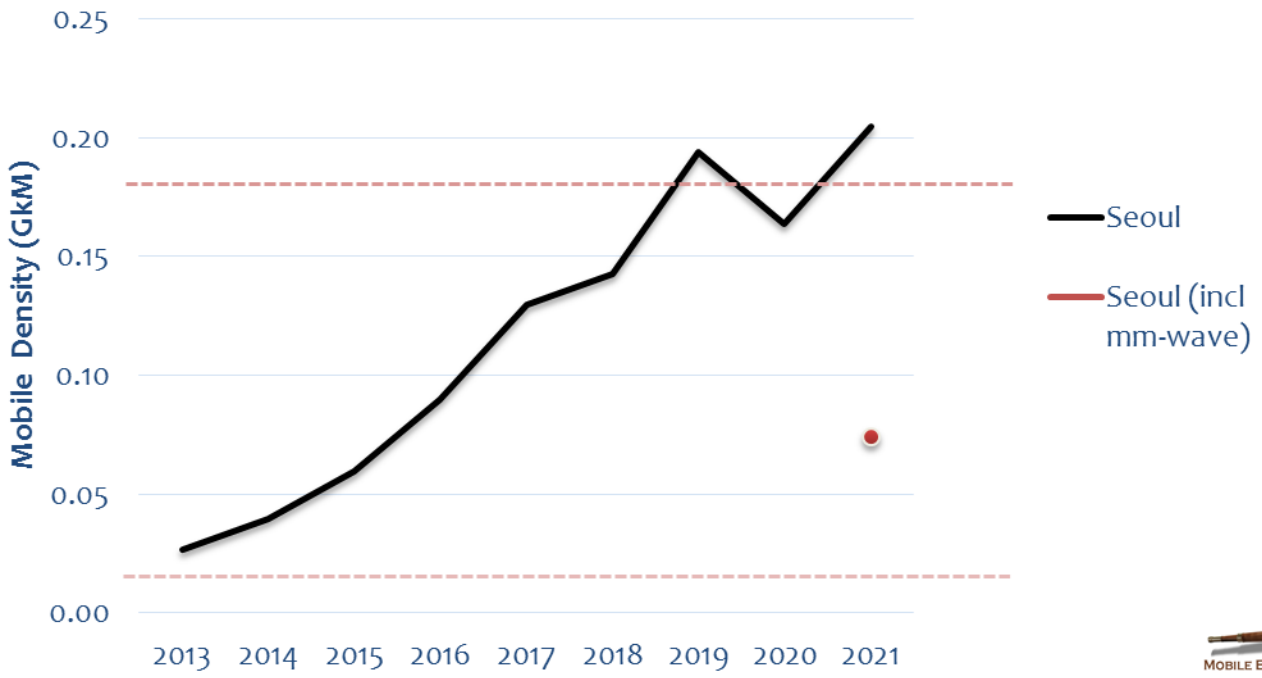

Figure 7 GkM outlook in Korea with 28 GHz spectrum

Source: Mobile Experts

Conclusions

The bottom line here is that GkM has, over the past five years, been a helpful tool in estimating the timing of small cell deployment. Moving forward, we expect mobile operators to be adding big blocks of spectrum—both licensed and unlicensed—in order to maintain mobile traffic density at a reasonably low level.

The next generation of investment only makes sense economically when the 4G network is heavily utilized. Nobody can make money on a network that is empty. We tentatively are setting a threshold of 0.18 GkM to predict 5G deployment in urban areas, based on two factors:

- At 0.18 GkM, the impact of LAA and other unlicensed options will be already taken into account and Massive MIMO deployment will be the next logical step in adding capacity at the lowest possible cost.
- We believe that network quality will start to suffer when LTE-Advanced networks reach about 0.18 GkM. This is not a precise estimate yet but reports from dense pockets in Korea/Japan indicate that small cells and Massive MIMO have limitations in LTE deployment somewhere above 0.1 GkM.
- New spectrum will be available in the 2020-2022 timeframe that will allow operators to manage their traffic density. Spectrum at 3-5 GHz and above 20 GHz will be very effective at "offloading" the mid bands and low bands to keep density below about 0.1 GkM.